ntario **Hydro**

RESEARCH DIVISION

91602
new 82-10

COMPLIMENTARY COPY
Please Credit Ontario Hydro Research if Reproduced in Whole or in Part

ontario hydro research division

CORROSION & TRITIUM TECHNOLOGY SECTION 1986 REVIEW AND 1987 PROGRAMS

Report 87-67-K

P.C. Lichtenberger
Supervising Scientist
Corrosion & Tritium Technology Section
Metallurgical Research Department

ABSTRACT

The projects and achievements of the Corrosion and Tritium Technology Section during 1986 are reviewed. Proposed projects and objectives for 1987 are outlined and an overview of the changes in direction of the work of the section is presented.

job	file	date	report no.
82-801-081	827.0	April 14, 1987	87-67-K

TABLE OF CONTENTS

	PAGE
1.0 INTRODUCTION	1
2.0 SECTION GOALS AND FUNCTION	1
2.1 Goals	1
2.2 Functions	1
3.0 STAFF AND MAJOR AREAS OF ACTIVITY	2
4.0 MAJOR CLIENT GROUPS	4
5.0 1986 RESEARCH PROGRAMS	4
5.1 Zirconium Corrosion Unit	4
5.1.1 Zirconium Corrosion Programs	4
- Modelling Corrosion and Deuterium Uptake	5
- Criteria for Identifying Pressure Tubes with High Rates of Corrosion and Deuterium Pickup	5
- Effects of PT Material on Corrosion and Deuterium Uptake	5
- Collaborative Research Programs	6
- Fuel Channel Out-Reactor Corrosion Under Simulated Conditions (FOCUS)	6
- Assessment of ZrO_2 on Pressure Tube (P/T) Materials	7
- Preparation of Thick Oxides for Carrier Fuel Bundles	7
5.1.2 Thermal Plant Programs	7
- Erosion-Corrosion of Feedwater Heaters, Nanticoke TGS	7
- Boiler Tube Analysis	8
5.1.3 Miscellaneous Corrosion Studies	8
5.2 Tritium Technology Unit	9
5.2.1 Tritium Programs	9

TABLE OF CONTENTS (CONT'D)

	PAGE
- Tritium Immobilization System (TIS)	9
- Tritium Laboratory	9
- Permeation Programs	10
- Getter Studies	10
5.3 Power Plant Materials Corrosion Unit	11
5.3.1 Steam Generator Corrosion Programs	11
- Chemical Cleaning Corrosion Testing	11
- Stress Corrosion Cracking of Steam Generator Tubing Alloys	11
5.3.2 Heat Exchanger Corrosion Programs	12
- Laboratory Electrochemical Testing, Pit Propagation Studies	12
- Laboratory Immersion Testing, Isothermal	12
- Test Rig I	12
- Test Rig II	13
- Fundamental Studies	13
- Turbine Rotor Disc Stress Corrosion Cracking	13
- Pitting Corrosion of Primary Heat Transport System Materials	14
- Flow System Development	14
- Waste Container Corrosion	14
6.0 1987 CORROSION RESEARCH PROGRAMS	14
6.1 Zirconium Corrosion Unit	14
6.1.1 Zirconium Corrosion Programs	14
- Modelling Corrosion and Deuterium Uptake	14

TABLE OF CONTENTS (CONT'D)

	PAGE
- Effects of PT Material on Corrosion and Deuterium Uptake	15
- Effects of Surface Modifications on Corrosion and D Uptake	15
- Fuel Channel Out-Reactor Corrosion under Simulated Conditions (FOCUS)	16
- Assessment of ZrO_2 on P/T Materials	16
- Preparation of Thick Oxides for Carrier Fuel Bundles	16
6.1.2 Thermal Plant Programs	16
- Boiler Tube Analysis	16
- Treatment to Prevent Exfoliation of Tube Bores	16
- Erosion-Corrosion of Feedwater Heater Tubing	16
6.1.3 Other Corrosion Studies	16
- Corrosion of Metals in Coal Ash - A Field Study	16
- Bruce NGS 'A' Vacuum Building Internal Inspection	17
- Miscellaneous	17
6.2 Tritium Technology Unit	17
6.2.1 Tritium Handling Program	17
- Tritium Immobilization Program	17
- Tritium Laboratory	18
6.2.2 Fusion/Tritium Related Programs	18
- Permeation Program	18
- Getter Program	18
6.3 Power Plant Materials Corrosion Unit	18
6.3.1 Steam Generator Corrosion Programs	18

TABLE OF CONTENTS (CONT'D)

	PAGE
- Stress Corrosion Cracking of Tubing Alloys	18
- Pitting and Crevice Corrosion of Tubing Alloys	19
- Evaluations of Tubes Removed from Service	19
6.3.2 Heat Exchanger Corrosion Programs	19
- Laboratory Electrochemical Testing	19
- Laboratory Immersion Testing	20
- Test Rig I	20
- Test Rig II	20
- Fundamental Studies	20
- Turbine Rotor Disc Stress Corrosion Cracking	20
- Pitting Corrosion of Primary Heat Transport System Materials	20
- Waste Container Corrosion	20
7.0 OVERVIEW	21
8.0 PUBLICATIONS AND PRESENTATIONS - 1986	23
DISTRIBUTION	24

ontario hydro
research division

TO: Dr. D. Mills
Director of Research

CORROSION AND TRITIUM TECHNOLOGY SECTION
1986 REVIEW AND 1987 PROGRAMS

1.0 INTRODUCTION

Before reviewing the major accomplishments of the Corrosion and Tritium Technology Section during 1986, the section goals and functions will be updated. The current organization of the section will also be briefly reviewed in terms of staff, major areas of activity, and key client groups.

Most of the section's work in 1986 fell into two broad program areas: Nuclear Generation and Thermal and Hydraulic Generation. As well, some work has continued in the Nuclear Waste and Transmission Systems program areas. This basic mix of work is expected to continue in 1987. After reviewing the 1986 work accomplishments, the major work packages planned to be undertaken this year will be summarized. Finally, a prediction as to the most probable direction of the section's future activities and initiatives in the medium and longer term, will be presented.

2.0 SECTION GOALS AND FUNCTION

2.1 Goals

The goals of the section may be summarized as follows:

- To provide a resource of specialized test facilities and advanced knowledge in various and specialized aspects of corrosion science, corrosion engineering, and metal/hydrogen isotope interactions.

- To carry out pure and applied research in these areas, together with supplying consultative, investigative and testing services to other units of the Corporation.

2.2 Functions

The section is organized to ensure that its expertise and resources may be used to:

- Assist in design of processes and systems to maximize efficiency of electricity production and transmission.

- Help maintain and/or improve process and system reliability.

- Help maximize component and system operating life.

- Forecast and plan for future demands for service including the area of lateral business opportunities.

3.0 STAFF AND MAJOR AREAS OF ACTIVITY

To manage the day-to-day activities of this section with a continuing heavy work load during 1986, the work programs have been consolidated among three key work units, as described below.

Zirconium alloy corrosion work in Unit 1 continues to be among the highest priorities in the section. This is being addressed by concentrating essentially the full time efforts of both Dr. B. Warr and Dr. A. Manolescu in this area. Dr. Warr is specifically addressing bulk alloy chemistry and metallurgy, metal-oxide interface phenomena, surface modification and corrosion/deuteriding modelling. Dr. Manolescu is addressing oxide growth and morphology, the influence of water chemistry, temperature, oxide thickness as well as material processing and surface conditioning. The group continues to concentrate on the highest priority Zr corrosion work and contract out supporting work where required. Additional staff technical resources to be acquired in 1987 should ease the heavy work load in this area. B. Reesor continued to work throughout the first half of the year, as a contract professional staff member, in the area of assessing potential lateral business opportunities through load growth associated with ceramics manufacturing in Ontario. Since June, he has been assigned a special project in the Divisional Projects Department to assist in assessing a Research Division role in Plasma Technology applications.

During 1986, the key parts of the Tritium Immobilization System (TIS) design and fabrication project were completed by Unit 2. In the January to April period, approximately 25 staff (including staff loaned from other Research Division Departments, AECL-CO, and various head office departments), worked full time to complete this work on schedule. The regular staff of this unit continued to be severely restrained throughout the full year with additional TIS support work, high priority work in support of the Canadian Fusion Fuels Technology Program (CFFTP), and completion of the new Divisional Tritium Laboratory. The work in this unit has been organized under the technical direction of Dr. W. Shmayda with key resources sharing basic, applied, and engineering work priorities. The staff have major responsibilities and capability in operation of the Tritium Laboratory, commissioning assistance to Darlington TRF, and the development of R&D and business opportunities in the areas of getter technology, hydrogen isotope permeation concepts, and tritium materials interactions. The conversion of R. Opatril's temporary employment contract to a regular technician position and the hiring of a contract technician to assist with commissioning of the Tritium Laboratory, has helped bolster the capability of this unit.

The work in Unit 3 during 1986 was heavily concentrated in HX corrosion including the building of 2 major test rigs. P. King has been given responsibility for technical direction of the unit's activities which are now mainly divided among HX corrosion (K. Lam) and steam generator corrosion (P. King). The planned addition of a third professional in this area during 1987 is expected to expand the unit's potential in developing increased capability in electrochemical methods, corrosion engineering, nuclear waste corrosion, and other corrosion related support work.

The current day-to-day operating organization of the section and key deliverables are as follows:

Zirconium Corrosion (Unit #1)

Engineers: Dr. A.V. Manolescu
Dr. B.D. Warr

Technologists: Mr. A.C. Headon
Mr. J.W. Mummenhoff

Technicians: Mr. E.M. Rasile

- Carry out pure and applied research into corrosion behaviour of metallic construction materials used in the generation and transmission of power in order to solve existing and anticipate future problems.

- Develop and maintain specialist and advanced capability in the Zr alloy corrosion field.

- Develop and test materials processes and measures for protection of structures and equipment against metal wastage due to corrosion.

- Provide failure analysis service and consultation on corrosion related problems to the Corporation.

Tritium Technology (Unit #2)

Engineers: Dr. W.T. Shmayda
Mr. J.O. Noga
Mr. A.G. Heics
Mr. N.P. Kherani

Technologists: Mr. K.D. Geiger
Mr. B.L. Fishbein

Technicians: Mr. M.J. Dudycz
Mr. R. Opatril

TIS Project Management - Dr. P. Mayer*

- Carry out pure and applied research into metal/hydrogen isotope interactions in support of the Tritium Removal Facility (TRF).

- Maintain and operate an active Tritium Laboratory in support of corporate research programs, and provide failure analysis service and consultation on tritium related problems.

- Provide a resource to undertake research and to act as a consultant to the Canadian Fusion Fuels Technology Project (CFFTP).

*Following wrap-up of the major design/fabrication activities of TIS, Dr. Mayer was re-assigned to other Metallurgical Research Department projects.

Power Plant Materials Corrosion (Unit #3)

Engineers: Mr. P.J. King
Mr. K.W. Lam

Technicians: Mr. S.W. Borda
Mr. L. Chee
Mr. L. Grant
Ms. B. Guest

- Carry out pure and applied research into the corrosion of metallic construction materials used in the generation and transmission of power and especially of Nuclear Heat Exchanger (HX) tubing (including Steam Generators), support structures, and associated components under operating and fault-water conditions.

- Carry out pure and applied research into the corrosion properties of possible container materials for the underground disposal of irradiated nuclear fuel.

- Develop, evaluate, and apply electrochemical corrosion monitoring techniques for corrosion research.

- Provide failure analysis service and consultation on related corrosion problems to the Corporation.

4.0 MAJOR CLIENT GROUPS

D&D - Design and Development Division
CFFTP - Canadian Fusion Fuels Technology Project
NGD - Nuclear Generation Division
THGD - Thermal and Hydraulic Generation Division
TTSD - Technical and Training Services Division

In the sections that follow under 1986 review, and 1987 programs, cross-references to major work program areas, and identification of principle investigators, and major client groups appear in brackets as follows:

(Major Clients; Major Work Program Area; Principle Investigator)

5.0 1986 RESEARCH PROGRAMS

5.1 Zirconium Corrosion Unit

5.1.1 Zirconium Corrosion Programs

The major objective of research programs in the area of Pressure Tube(PT) corrosion is to predict corrosion and hence Deuterium(D) levels in reactor PTs. This is an important corporate objective since the frequency and size of PT blisters arising from PT-Calandria Tube contact, can be directly related to D levels in the PT. In addition to the evaluation of data from removed PTs (modelling), we have performed experimental work aimed at improving our fundamental

understanding of the processes involved in corrosion and D uptake. A secondary objective of our corrosion program is to develop and evaluate practical techniques to minimize corrosion and D pick-up. Some PT coatings have been tested.

To handle the large amount of data available on zirconium corrosion and hydrogen uptake, a literature database was established with IBM-compatible software. This allows for rapid review of literature with specified key words. The database will be expanded and updated as more information is found or becomes available.

Modelling Corrosion and Deuterium Uptake

Predictions of Equivalent Hydrogen levels in operating pressure tubes are required for reactor maintenance decisions such as SLAR, REFAB and RETUBE. There is little research data on the long-term in-reactor performance of Zr-2.5 wt % Nb in CANDU environments. Thus, any predictions of pressure tube performance must be based on analysis of the limited data available from examination of removed pressure tubes.

Predictions of equivalent hydrogen levels have been made for Pickering 3 & 4 pressure tubes for the years 1990, 1995 and 2000. If a linear relationship between deuterium concentration and reactor operating time, is assumed, predicted equivalent hydrogen levels are acceptably low, not exceeding 26 ppm by 2000. However, assuming D pickup rates are accelerating, by 1990 at locations where calandria tube contact is possible, reasonably conservative predictions of equivalent hydrogen levels of 45 and 72 ppm may be predicted by 1995 and 2000 respectively.

Given the present limited data base it is not yet possible to decide between the linear versus accelerating models for D pickup. Therefore, it is essential that further PTs be removed and examined in order to distinguish between these two predictive models.
(D&D; TTSD; Nuclear Generation; B.D. Warr)

Criteria for Identifying Pressure Tubes with High Rates of Corrosion and Deuterium Pickup

The role of impurity elements in corrosion and D pickup has also been examined using both modelling and experimental approaches. There is presently insufficient evidence from removed PTs to reach definitive conclusions. However, taking the data as a whole, Fe and Cr appears to increase D pickup in the high temperature regions of the pressure tube, whilst leaving lower temperature regions unaffected. It is also possible that a threshold level of impurities exists below which D uptake rates are acceptably low. Based on the limited evidence to date, it has been recommended that for future specifications, impurity levels in PTs should be minimized.

Experimental work was initiated in 1986 to develop out-reactor correlations between pressure tube material composition (impurity levels), and rate of oxidation and D pickup. This will assist in selection of PTs for inspection and removal. However, the sample containing the highest Fe content appears to show the highest linear corrosion rate.

Effects of PT Material on Corrosion and Deuterium Uptake

Samples of silica-coated material produced by a chemical vapor deposition process, and received from Harwell, were exposed in a static autoclave (aqueous environment, pH~10, 340°C). Samples were examined using visual and electron microscopy. Based on our observations, we conclude that such coatings would be unsuitable for use in the CANDU environment. Chromium coatings were also evaluated. Due to the uneven nature of the coatings, samples were not tested by autoclave exposures. (OHRD; Nuclear Generation; B.D. Warr/J.W. Mummenhoff)

Collaborative Research Programs

Due to the limited resources and the importance of zirconium corrosion research to the corporation, grants have been awarded to three Ontario universities to perform collaborative research programs in the following areas:

- Mechanism of Hydrogen Absorption in Zirconium Alloys - A research grant was awarded to Professor C. Ward of the University of Toronto to perform fundamental studies in the area of hydrogen absorption of zirconium alloys. The objectives of the program are several, viz - to determine the rate controlling step for D absorption, and rate constants in pure and alloyed zirconium. (OHRD; D&D; Nuclerar Generation; B.D. Warr)

- Microstructural Analysis of Zr-2.5 wt % Nb - Professor D. Northwood of the University of Windsor was awarded a research grant to investigate by transmission electron microscopy the microstructure and distribution, size and nature of intermetallic particles in samples taken from PT offcuts. Early results of this work in 1986 have identified Zr_2Fe intermetallic particles in samples with Fe levels above 500 ppm. No intermetallics have been identified in samples with lower levels of Fe, indicating a possible Fe threshold below which Fe-containing intermetallics are not present. (OHRD; D&D; Nuclear Generation; B.D. Warr)

- Ion Implantation - A grant has also been awarded to Professor D. Thompson of MacMaster University to produce Zr-2.5 wt % Nb samples with ion implantated surfaces. MacMaster U. have developed a unique capability in this area. Previous work at Harwell has shown that ion implantation can significantly reduce zirconium oxidation rate when certain implanted species are used. (OHRD; D&D; Nuclear Generation; B.D. Warr)

Fuel Channel Out-Reactor Corrosion under Simulated Conditions (FOCUS)

To quantify trends and produce reference base line out-reactor zirconium corrosion data, the FOCUS program was defined and initiated. The objective of this program is to establish long term out-reactor corrosion and H_2 pick-up data for P/T materials in order to provide a data base to assist in the development of a P/T corrosion model and computer code for in-reactor performance predictions. The program consists of the following two phases:

Accelerated tests, with preoxidized Zr-2.5 Nb samples (up to 30 μm thick oxide) and temperatures up to 350°C, are being carried out in static and refreshed autoclaves to characterize the post-transition corrosion and hydrogen pick-up kinetics vs time, temperature, H_2/O_2 ratio, and material condition.

Long term tests, to determine the specific pre-transition, transitory and post-transition corrosion kinetics of Zr-2.5 Nb are also being carried out.

During 1986, static autoclave tests with up to 4 months exposure at 250, 275, 300 and 325 were completed. A computer program was written for storage and analysis of experimental data. Preliminary results indicate that the corrosion rates increase with temperature from 250° to 325°C for all examined pressure tube materials, (Zr-2.5 Nb β and non β-quenched and Zr-2). The Zr-2 coupons exhibited the lowest corrosion rate. The oxide scale formed on Zr-2.5 Nb β-quenched is more adherent and protective than that formed on non-β-quenched alloy.

Four corrosion loops (refreshed autoclaves) required for tests to establish the effect of H_2/O_2 (ppm/ppm) ratio on corrosion rate and hydriding of pressure tube materials were installed and commissioned at AECL-CO. (D&D/TTSD; Nuclear Generation; A.V. Manolescu)

Assessment of ZrO_2 on Pressure Tube (P/T) Materials

Structural, morphological and compositional characteristics of ZrO_2 on P/Ts are also required for the development of a predictive corrosion and hydriding model, and to understand the effects of radiation, PHT coolant chemistry and oxide scale spallation on P/T performance under both boiling and non boiling conditions. Furthermore, this information will assist development of a reliable method to grow thick out-reactor oxides, simulating the in-reactor scales on P/T samples, required for in-reactor and out-reactor accelerated tests.

During 1986, morphological analysis (optical and scanning electron microscopy) of ZrO_2 on P1-K18, P3-J09 and P4-N16 P/Ts was completed. The out-reactor formed oxide scales in LiOH solutions at 300-360°C were analyzed. Based on comparison of morphological characteristics of in- and out-reactor scales, experimental conditions were selected to artificially grow representative thick oxide scales (5-20 μm).

Samples of P/T's removed from operating reactors were selected and are being re-exposed under simulated PHT coolant conditions in static autoclaves (AECL-WNRE) to evaluate their "memory effect". (D&D; Nuclear Generation; A.V. Manolescu)

Preparation of Thick Oxides for Carrier Fuel Bundles

During 1986, two types of tests that produce promising results (scales that are thick, adherent to the metal/oxide interface and simulate the most important characteristics of the in-reactor scales were identified: tests carried out in 0.5 g/L LiOH solution at 360°C and tests performed in 2.5 g/L LiOH solution at 360°C.

Based on these results, the corrosion tests required to preoxidize corrosion coupons for carrier fuel bundles that will be exposed to PHT coolant at Pt. Lepreau and Bruce NGS were initiated. (D&D/TTSD; Nuclear Generation; A.V. Manolescu)

5.1.2 Thermal Plant Programs

Erosion-Corrosion of Feedwater Heaters, Nanticoke TGS

Both field and laboratory tests have indicated that Admiralty brass tubed 4th point low pressure feedwater heater tubes from Nanticoke TGS fail due to a flow assisted localized corrosion process of electrochemical nature initiated from the internal tube surface exposed to feedwater.

A feedwater monitoring program has shown that increased copper transport products are likely caused by corrosion induced by the decomposition products of morpholine (added for feedwater pH control). Based on these findings, the recommendation to change from morpholine to ammonia for pH control was implemented in 1985 in all units at Nanticoke TGS. During 1986, a corrosion loop was built for installation at Nanticoke TGS to evaluate chemical treatments to prevent further damage of feedwater heater tubes. Examination of feedwater heater tubes from the 3rd point heater at Nanticoke TGS, Unit 1 was carried out to establish the extent of corrosion-erosion damage at this location. Only a few inactive localized damage sites were identified indicating that corrosion of Admiralty brass decreased as a result of this change in

water chemistry. This was also confirmed by analysing the internal condition of waterwall tube sections from the same unit at Nanticoke TGS; the results showed that there were no metallic copper depositions in the waterside scale. The transport of the copper products resulting from corrosion of feedwater heater tubes was apparently reduced significantly due to the change from morpholine to ammonia for pH control. (TTSD; Thermal Generation; A.V. Manolescu)

Boiler Tube Analysis

At the request of Central Thermal Services (CTS), a number of waterside scale analyses were performed on boiler tubes removed from Lambton GS, Nanticoke TGS and Lakeview TGS. The objective of these anslyses was to characterize the morphology of the scales and deposits and to evaluate the extent of waterside corrosion before (so as to plan effective cleaning procedures) and after acid cleaning of the units (to confirm the effectiveness of such procedures). (TTSD; Thermal Generation; A.V. Manolescu)

5.1.3 Miscellaneous Corrosion Studies

Numerous short term tests were conducted or consultation provided on underground, aqueous and atmospheric problems, such as:

- 1986 Corrosion Inspection at the Mothballed BHWP-D
  (D&D; Nuclear Generation; A.C. Headon)

- Corrosion of Aluminum Conductor at Caledonia TS
  (Western Region; A.C. Headon)

- Corrosion of Aluminum Storage Tanks by D_2O
  (D&D; Nuclear Generation; A.C. Headon)

- 1986 Corrosion Inspection - BNGS 'A' Intake Structure
  (NGD; Nuclear Generation; A.C. Headon)

- BNGS 'B' - Examination of Emergency Service Water Piping
  (TTSD; Nuclear Generation; a.C. Headon)

- Corrosion of Post Tensioning Cable Barrels in Parking Garage
  (D&D; NGD; Nuclear Generation; A.C. Headon)

- Corrosion of Tower Legs and Guy Anchors at Gibson JCT
  (Western Region; A.C. Headon)

- Extent of Corrosion of Structural Steel at O.P.G.S. Surge Tank
  (Civil Works; Thermal & Hydraulic Generation; A.C. Headon)

- Darlington GS A Buried ESW Piping Corrosion Risk
  (D&D; Nuclear Generation; A.C. Headon)

- Cathodic Protection Survey Buchanan FC and TS
  (Western Region; A.C. Headon)

- Corrosion Survey of Corrosion Monitoring Rods Pickering NGS 'B" Fuel Bay
  (NGD; Nuclear Generation; A.C. Headon)

- Corrosion Survey DeCew Falls Penstocks
  (Civil Works; Thermal & Hydraulic Generation; A.C. Headon)

- Nanticoke TGS Corrosion Survey Underground Oil Piping
  (TGD; Thermal Generation; A.C. Headon)

- Water Heater Consultation
  (Supply Division; A.C. Headon)

- Darlington Service Transformer - Corrosion Evaluation
  (Darlington Project; Nuclear Generation; K.W. Lam)

5.2 Tritium Technology Unit

5.2.1 Tritium Programs

Tritium Immobilization System (TIS)

The Tritium Removal Facility is under construction at Darlington Nuclear Generating Station. Its function is to selectively extract tritium from the heavy water used in the Moderator and Primary Heat Transport Systems of CANDU reactors. The Tritium Immobilization System is a subsystem of the TRF. Tritium gas is transfered from the cryogenic columns to the titanium storage beds in prescribed quantities via the TIS.

This unit undertook the detailed design, procurement, fabrication and assembly of the TIS subsystem. Both AECL-SPEL and the Electrical Department at OHRD participated in this work. The fabrication of equipment and systems, spanning three years, was shipped to site on April 15, 1986. Assembly of the various appendages and link-ups to the remainder of the TRF continued throughout 1986. Personnel within the unit continue to participate with both Darlington Engineering and Darlington Construction in this phase. Preliminary subsystem operation is expected to begin in mid 1987.

Degassing of approximately 53, eight hundred gram charges of titanium sponge, for the Darlington TRF immobilization tritium containers (ITC) has been completed.

Specialist consulting expertise on the Tritium Applications Program (TAP) was supplied to Darlington Engineering in the areas of design and specification, as requested.
(D&D; Nuclear Generation; P. Mayer/W.T. Shmayda/J.O. Noga/A.G. Heics)

Tritium Laboratory

A laboratory designed to safely handle tritium has been under construction during the past year. Structural work proceeded early during the year with mechanical and electrical outfitting during the latter half of 1986. Currently, many of the facilities are in place and under test. The construction phase of the lab is 98% complete. First tritium operations are expected in March.

The lab has 230 m^2 of floor space with three different types of work stations available to the researchers; fume hoods, controlled atmosphere stations and gloveboxes. Each sight provides access to the following services: electrical (110 V, 208 V, 550 V), water and drainage, inert gas, compressed air, link-up with the stack and a vacuum effluent discharge line.

The lab will be licensed to operate with a vulnerable inventory of 3 kCi. The gas will be stored in and dispensed from a Tritium Storage and Delivery System (TSDS).

Tritium labelling of a polyssacharide for NRC has been carried out in the radiation materials laboratory. This real Tritium experience will assist start-up of the new Tritium Laboratory. (OHRD; Nuclear Generation; K.D. Geiger/W.T. Shmayda)

Permeation Programs

This work is a continuation of a program initiated in 1983. Hydrogen permeation through composite materials can depend on the direction of movement through the composite layer. Material combinations and upstream operating pressures can be selected to make the flow through the composite essentially unidirectional. A pump which uses this flow rectification property has been built and tested. Efforts are currently underway to optimize the pump properties. In a second although related work area, the hydrogen permeation characteristics through pure iron have been measured over a broad range of pressures and membrane temperatures for both atomic and molecular species. A permeation probe has been constructed and installed on a tokamak to measure the radial atomic hydrogen flux to the wall during machine operation. This probe represents a novel and unique method for such measurements. Correlations of plasma properties with the radial flux to the wall are underway.
(CFFTP; Nuclear Generation; OHRD; W.T. Shmayda)

Getter Studies

A Getter Evaluation Facility equipped with ultra high vacuum systems, radio frequency mass spectrometer, operable in a once through flow or circulating mode, and bakeable to 400°C has been constructed. The facility will permit evaluation of potential getters for tritium storage, scavenging of tritium, and fusion exhaust treatment. An experiment to determine the efficiency of a zirconium-iron alloy getter to extract a variety of impurities from a once through flow helium stream began late in the year. Preliminary results indicate that continuous purification of tokamak exhaust at low pressures is feasible.

A collaborative experimental program, carried out at the Tritium Systems Test Assembly, Los Alamos National Laboratory, has shown that elemental tritium in a nitrogen or noble gas atmosphere can be removed by a zirconium-iron alloy getter to levels less than tens of microcuries per cubic meter. Experimental results also show that the presence of trace levels of impurities, such as O_2, CO and NH_3, have minimal influence on the removal of tritium. The immediate implication of these results is that the usual titanium getters often used in glovebox purification systems (which are prone to shortened life due to oxygen surface contamination) can be replaced by the zirconium-iron alloy. The long term implication of these results is the potential replacement of existing tritium scavenging systems which are currently based on detritiation via oxidation of hydrogenic species, (a more hazardous form), followed by adsorption of the oxides on molecular sieves.

A three kilogram Uranium storage bed was designed and built for Darlington TIS. Testing has been successfully completed and the bed capacity confirmed to be one million curies. The bed's ability to accept 11 loadings under conditions identical to those expected in the TIS loop have been successfully carried out. Additional beds for the Tritium Applications Program (TAP) loop will be built. (CFFTP; OHRD; N.P. Kherani/W.T. Shmayda)

5.3 Power Plant Materials Corrosion Unit

5.3.1 Steam Generator Corrosion Programs

The steam generator corrosion program was initiated in the mid 1970's to assess the probability of significant corrosion failures of alloy tubing in Ontario Hydro nuclear steam generators and to define the limits of secondary water chemistry for safe operation. This program is closely associated with a program in the Corrosion Chemistry and Decontamination Project Group, Chemical Research, to study chemistry conditions in nuclear steam generators. The level of effort in 1986 was limited due to the high priority placed on the heat exchanger corrosion program. All steam generator corrosion projects are ongoing.

Chemical Cleaning Corrosion Testing

Only a small amount of work was performed in 1986. Weld samples previously exposed to chemical cleaning trials were removed from an autoclave test started in 1985 to examine long term effects associated with subsequent steam generator operation. The examination involved visual comparison of samples with photographs taken prior to the autoclave exposure. Surface features apparent in the photographs were still clearly visible after autoclaving and all samples were uniformly covered in black oxide, as expected from exposure to boiler conditions. It is concluded that no further preferential attack occurred at the welds, and tentatively that the long term corrosion effects of a single chemical clean on carbon steel welds are negligible.
(TTSD; Nuclear Generation; P.J. King)

Stress Corrosion Cracking of Steam Generator Tubing Alloys

This project was initiated in 1983 to obtain data on the stress corrosion of tubing alloys N06600, N08800 and N04400 in steam generator environments encountered at Ontario Hydro Nuclear Generating Stations. The influence of lower operating temperatures (15 to 30°C below PWR) and chemical impurities on cracking susceptibility are of particular interest. The test program involves exposure of sections of steam generator tubing or alloy rod to the desired environmental conditions in a high temperature, circulating water system. A tensile stress is applied with a constant extension rate test (CERT) system, or alternatively may be obtained by plastic deformation (eg, bending).

A short program of baseline CERT tests was performed on cold worked N06600 rod samples at a strain rate of $10^{-7}s^{-1}$. Test environments were deaerated (with N_2) pH 9 or pH 10 water at 270°C to 280°C. The maximum loads and the elongations to failure were not reduced from those determined in air at room temperature, indicating ductile failures. Metallographic examination confirmed that no cracking had occurred on any of the samples.

A program of N06600 steam generator tube testing was initiated with CERT tests at a strain rate of $2 \times 10^{-7}s^{-1}$ in 316°C, pH 10 water containing 100 ppb of oxygen. The tests were terminated after 20% elgonation. Metallographic examination of samples after testing revealed no cracking.

An autoclave exposure of bent N06600 tubing and rod samples was completed. The test environment was deaerated pH 12 water at 330°C. Metallographic examination of removed samples revealed no cracking after 1250 hours. (TTSD; Nuclear Generation; P.J. King)

5.3.2 Heat Exchanger Corrosion Programs

The heat exchanger corrosion program was initiated in 1983 to investigate means of minimizing the localized corrosion of N08800 tubed moderator heat exchangers. Since that time, the program has expanded considerably due to the continuing need for pitting and crevice corrosion information specific to Ontario Hydro's lakewater cooled heat exchangers. Activities in the program in 1986 were in the five major project areas outlined below. Most effort was expended on the two test rig systems, interfering with the ability to make major advances in the laboratory parts of the program.

Laboratory Electrochemical Testing, Pit Propagation Studies

In 1986, potentiostatic polarization studies were performed with N08800, N08825 and N08028 samples of a matrix of potential-temperature-time combinations to obtain initiation data, refine propagation data obtained from earlier tests, and investigate the influence of temperature on both initiation and propagation.

Results so far lead to two conclusions:

1. The conditions leading to crevice corrosion of N08800 in moderator heat exchangers are sufficient to initiate attack on both N08825 and N08028. Thus, some attack of either of these alloys is to be expected in a severely fouled heat exchanger (with extensive deposits and silt).

2. Attack on N08825 or N08028 may not propagate, or may propagate slowly compared to N08800 since the more favourable morphology would promote repassivation under conditions of natural exposure. (TTSD, D&D; Nuclear Generation, K.W. Lam)

Laboratory Immersion Testing, Isothermal

Two isothermal immersion test exposures were started in 1986. A number of alloys mounted in crevice assemblies (including N08800, N08825, N08028 and N06625) are being exposed to Lake Ontario water at 75°C and 85°C. Total durations of one to two years are planned. Visual examination of samples after 133 days at 75°C and 53 days at 90°C did not reveal any evidence of corrosion. The samples were not removed from the test environments so that crevice conditions would not be disturbed, making examinations necessarily cursory.
(TTSD; Nuclear Generation; P.J. King)

Test Rig 1

This project was initiated in 1983 to obtain corrosion information, especially in the short term (1 month to 1 year), under simulated service conditions employing appropriate heat flux, water velocity, temperature, and cooling water chemistry. Installation of the test rig, consisting of three heat exchanger vessels in parallel, at Pickering NGS was completed by July. Following a brief commissioning and shake-down period, a short term test program was initiated in August to obtain data on the effects of chemical cleaning and chlorination on fouling and tubing performance.

The tube bundles were periodically removed from the shells, inspected, and photographed to record the progress of fouling. The system operated for a total of about 13 weeks prior to the first tube removals.

The principal results of this first test exposure are that:

1. scale deposits form very rapidly and uniformly

2. silting occurs more slowly and, as expected, is less uniform

3. a realistic simulation of PNGS B moderator heat exchangers is obtained - test bundles were taking on a characteristic dusty, grey appearance and fibrous biological material was trapped on tubes and baffles

4. there is no discernible difference in the deposition on cleaned compared to non-cleaned tubes

5. there is no corrosion on any tubes discernible by close visual inspection

The chlorination was not operational for a sufficiently long period for any observation of its effects to be made. (TTSD; Nuclear Generation; P.J. King)

Test Rig II

This project was initiated in 1985 to obtain corrosion information, especially in the longer term (1 year to 5 years), under simulated service conditions. Fabrication of the heat exchanger vessels and construction of the supporting system were the major tasks for this project in 1986. The system was delivered to Darlington NGS in December, following a preliminary checkout confirming proper pump, heater, and valving operation.
(D&D, TTSD; Nuclear Generation; P.J. King)

Fundamental Studies

A series of 12 alloys of a fixed chromium content and with very low impurity levels was obtained for investigations of the role of major alloying constituents on the corrosion behaviour of nickel alloys in lakewater. Electrochemical testing was performed in concentrated HCl solutions to examine the passivation behaviour of these pure alloys. The results show not only molybdenum but also nickel-iron ratio to be significant in passivation processes. This demonstrates that in connection with resistance to crevice corrosion, it is important to consider all major alloying elements, not just those considered directly responsible for passivity. This work is being carried out at MIT. (TTSD; Nuclear Generation; P.J. King)

Turbine Rotor Disc Stress Corrosion Cracking

This project was started in 1982 to determine crack growth rates and obtain crack initiation data for LP turbine disc material in simulated turbine environments. The test program involves exposure of test specimens to the desired environment in 4 vessels connected in series in a closed circuit flow system. Specimens for crack growth are 2.54 cm (1") thick wedge-open load (1T-WOL), fatigue precracked and loaded to 60 MPa$\sqrt{m}$; those for crack initiation are of the 4-point bend type loaded to 90% of yield stress, and with a double sample arrangement to provide a crevice.

A new test series, #3, was started in 1986 to investigate the senstivity of crack growth rates to environmental changes. A circulating solution of 10% caustic and temperatures of 120°C, 140°C, 150°C, and 160°C were chosen for environmental conditions. Principal tasks in 1986

were specimen and test system preparation. The test exposure began late in October because of delays due to heat exchanger work; with this and several system component failures, total exposure by year end was less than expected at 1260 hours.
(TTSD; Nuclear Generation; S.W. Borda)

Pitting Corrosion of Primary Heat Transport System Materials

A preliminary assessment was provided on the probability of further growth of pits found in the carbon steel feeders of Pickering NGS, Units 1 and 2. Based on a short duration static autoclave test and the high temperature corrosion properties of carbon steel, it was concluded that the probability of further significant pit growth in feeders under power operating conditions is low. However, the effect of fluid flow on further pit growth is not known and there are concerns of further pit growth under shutdown conditions. It was recommended that these effects be studied. (TTSD, Nuclear Generation; K.W. Lam)

Flow System Development

To experimentally study the corrosion properties of materials in major nuclear plant systems requires appropriate simulation of operating environments. The capability to include bulk flow in such simulations has been lacking. To rectify this, an economical, flexible and compact system for evaluating flow effects has been designed and built.

The flow system builds around an impeller pump enclosed in a container. Corrosion coupons may be placed either within the channel of the pump or outside it. For high temperature studies, an autoclave is used as the container. A motor outside of the container drives the pump. Provision is designed into the container for fluid refreshment and chemical and electrochemical monitoring. (TTSD; Nuclear Generation; K.W. Lam)

Waste Container Corrosion

Copper is one of the number of materials being considered for possible use in fabricating containers for future disposal of irradiated nuclear fuels in hard rock formations. A program to evaluate its corrosion performance is in progress. Long term corrosion tests have been performed by immersing copper coupons in groundwater-bentonite slurries for durations of up to ~1 year. Tests to examine the effects of sulphide and radiolysis were completed in 1986.

Based on the nature of the observed attack (general corrosion and pitting), and the worst case exposure conditions examined here, the rate of penetration of a copper container should not exceed 200 μm/y. Using this rate, a design life of 500 years could be achieved with a 10 cm thick container. (D&D; Nuclear Generation; K.W. Lam)

6.0 1987 CORROSION RESEARCH PROGRAMS

6.1 Zirconium Corrosion Unit

6.1.1 Zirconium Corrosion Programs

Modelling Corrosion and Deuterium Uptake

Additional data from removed PTs, and OHRD and AECL research programs, will be included in the data base. Presently it is planned to remove PTs from Pickering 3 and 4 in 1987. It is also

hoped to obtain additional data from external sources such as Japanese and Russian programs where possible. The model will be updated to include the above data. Effects of PT material, for example impurity levels and processing history, and heat transport system environment (H:O ratio, boiling, temperature) will be included in the model. Predictions will be provided as required, and as further information becomes available.
(D&D; COG; Nuclear Generation; B.D. Warr)

Effects of PT Material on Corrosion and Deuterium Uptake

In 1987, this will be a joint program with AECL-RC. OHRD's role will be to test actual PT material with a range of composition and thermomechanical properties. At AECL-RC, the work will involve mostly the production and testing of pure master alloys. Also, surfaces will be modified by ion implantation of impurity elements in conjunction with Prof. D. Thompson, McMaster University. Samples will be exposed in static/refreshed autoclaves containing D_2O at a range of temperatures between 250-360°C.

We hope to be able to develop correlations between linear and accelerated rates of corrosion, and D pickup, and material thermo-mechanical processing (eg, beta vs non-beta quenched), and impurity content by discriminant analyses. We will be looking carefully at samples from PT offcuts from the same series as P3-J09 and P4-K10 in order to understand why these PTs show low and high D uptake rates respectively. Fundamental work on mechanisms and rates of D adsorbtion in pure and alloyed zirconium will be performed in conjunction with Prof. C. Ward, of the University of Toronto. Also, to provide a fundamental understanding of the effects of impurity concentration and thermo-mechanical processing on PT microstructure, Transmission Electron Microscopy will continue to be performed in conjunction with Prof D. Northwood of the University of Windsor. Further, consideration is being given to the utilization of in-situ Laser Raman Spectroscopy during autoclave testing, to develop fundamental understanding of corrosion and D uptake processes. This work involves close collaboration with the Dr. L. Mannick of the Science Section (OHRD).
( )&D; COG; Nuclear Generation; B.D. Warr/J.W. Mummenhoff)

Effects of Surface Modifications on Corrosion and D Uptake.

In 1987, we will be pursuing work in this area jointly with AECL-RC. Samples of PT will be surface modified by ion implantation of various species by Professor D. Thompson of McMaster University. Modified samples will be exposed in autoclaves at OHRD to evaluate corrosion and D pickup performance. Samples will also be modified by other processes such as sputter-deposition, Cr plating, laser modification, and plasma coating, followed by autoclave exposures to determine the resultant material performance. The feasibility and potential benefits arising from in-situ remedial treatments (eg, removal of thick oxides to reduce corrosion rate) will be determined. Effect of in-reactor surface modification (eg, gauging and fuel scratches, and fretting, on corrosion and D pickup performance will also be evaluated.

Recent data from removed PTs P4-K10, N16 and P3-F13 may be interpreted to imply increased rate of D uptake. Remedial measures developed in this program may be able to reduce D uptake rates to acceptable levels, or provide increased assurance of low rates of D pickup in replacement PTs. (D&D; COG; Nuclear Generation; B.D. Warr)

Fuel Channel Out-Reactor Corrosion under Simulated Conditions (FOCUS)

Scheduled activities during 1987 include continuation of long term tests in static autoclaves and analyses of the samples removed periodically from autoclaves. The tests in refreshed autoclaves, to establish the effect of H_2/O_2 ratio on corrosion and hydriding of P/T materials, will be initiated and the 9-month exposure tests completed. The 6-month accelerated tests using pre-oxidized samples will also be completed.
(D&D/TTSD; COG; Nuclear Generation; A.V. Manolescu)

Assessment of ZrO_2 on P/T Materials

The program to assess ZrO_2 on P/T materials will continue in 1987 with the objective to further develop techniques for structural and compositional characterization of the scales. The scheduled activities for 1987 include characterization of scale porosity and grain structure of both in- and out-reactor scales using STEM and SEM techniques. To establish the memory effect of in- and out-reactor scales, corrosion tests carried out by re-exposing P/T samples in static autoclaves at WNRE will continue. (D&D; COG; A.V. Manolescu)

Preparation of Thick Oxides for Carrier Fuel Bundles

The scheduled activities for 1987 include the continuation of corrosion tests in 0.2 g/L aqueous solution of LiOH at 360°C to further improve the P/T sample pre-oxidation methods and preparation of thick oxide scales for carrier fuel bundle programs as and when requested by CNS. (TTSD; COG; Nuclear Generation; A.V. Manolescu)

6.1.2 Thermal Plant Programs

Boiler Tube Analysis

Service failure and boiler tube analysis will be continued as requested by CTS and/or thermal stations. (TTSD; Thermal Generation; A.V. Manolescu)

Treatment to Prevent Exfoliation of Superheater and Reheater Tube Bores

The evaluation of treated and untreated sections (using boron containing formulations) to be removed in 1987 from Lambton TGS, Unit 2 will continue. A final report will be issued describing the results. (CEA; Thermal Generation; A.V. Manolescu)

Erosion-Corrosion of Feedwater Heater Tubing

The installation of a corrosion test loop at Nanticoke TGS will be completed in 1987. The tests designed to evaluate long term performance of stainless steel tubing and the effectiveness of tube and/or feedwater treatments will be initiated in the second half of 1987.
(TTSD; Thermal Generation; A.V. Manolescu)

6.1.3 Other Corrosion Studies

Corrosion of Metals in Coal Ash - A Field Study
The coupons of copper, aluminum, stainless steel, galvanized steel and carbon steel that have been exposed for 5 years in fly ash, bottom ash and granular 'A' material will be excavated, cleaned and examined for corrosion. Corrosion rates for the various metals will be calculated.

Visits will be made to fly ash disposal areas that have been in use as building sites, parks and for highway construction where buried metals of construction will be compared with the corrosion of the test coupons. (TGD; Thermal Generation; A.C. Headon)

Bruce NGS 'A' Vacuum Building Internal Inspection - Bruce NGS 'A' will be shutdown for the month of May 1987. During this shutdown, a corrosion inspection of all metallic components inside the Vacuum Building will be made. Components not meeting set criteria will be replaced.

A report will be prepared following the investigation. (D&D; Nuclear Generation; A.C. Headon)

Miscellaneous Corrosion

(a) Nanticoke GS and Darlington NGS - Cathodic Protection of Underwater Boiler Blowdown Piping (D&D; Thermal and Nuclear Generation; A.C. Headon)

(b) Initial Corrosion Rates of Metals in LiOH and $LiNO_3$
(CFFTP; Nuclear Generation; A.C. Headon)

(c) 1987 Corrosion Inspection at the Mothballed BHWP-D
(D&D; Nuclear Generation; A.C. Headon)

(d) 1987 Corrosion Inspection BNGS 'A' Intake Structure
(BNPD; Nuclear Generation; A.C. Headon)

(e) Pickering 'B' GS Buried Emergency Water System Piping - Corrosion Risk
(D&D; Nuclear Generation; A.C. Headon)

(f) In-Situ Techniques for the Detection and Measurement of Corrosion in Operating Systems
(Nuclear Generation; A.C. Headon)

(g) Water Heaters Consultation
(Supply Division; A.C. Headon)

6.2 Tritium Technology Unit

6.2.1 Tritium Handling Programs

Tritium Immobilization Program

The work effort anticipated in support of the Tritium Immobilization System will take two forms; participation in the commissioning of the system and undertaking studies in the laboratory to anticipate tritium related operational problems within the Tritium Removal Facility. On the latter point, two specific concerns will be addressed initially; the rate of tritium pick up by oils and methods of detritiating metal components once they have been exposed to high levels of tritium. This work will be carried out in the Tritium Laboratory.
(DNGS; Nuclear Generation; W.T. Shmayda/J.O. Noga/A.G. Heics)

Tritium Laboratory

The Tritium Storage and Delivery System is under construction. The work will continue in the current year to see completion of the loop; integration of the loop into a glovebox, outfitting of the loop with a programmable controller and a dedicated computer. Development of tritium lab operating procedures are underway. This work is expected to see the laboratory fully operational in the second half of the year.

Additionally, a number of work stations with integral cleanup systems will be brought on line within the lab. These stations will provide inert atmosphere environments for researchers use. (OHRD; Nuclear Generation; W.T. Shmayda/K.D. Geiger)

6.2.2 Fusion/Tritium Related Programs

Permeation Program

The study of hydrogen permeation through composites will continue. The work will focus on optimizing the tritium pump, through the use of RF as a source of atoms rather than on a hot filament. On a second front, the utility of permeation through composites to separate hydrogen isotopes from impurities under conditions typically found in a reactor exhaust stream will be studied. The atomic hydrogen flux to the walls of tokamaks and its dependence on discharge parameters will be studied at TEXTOR, a tokamak designed to study plasma wall interactions. (NRC; CFFTP; Nuclear Generation; W.T. Shmayda/N.P. Kherani)

Getter Program

The application of getters to remove chemically bound tritium will continue into the upcoming year. The potential to scavenge this tritium under typical reactor exhaust conditions will be studied. In this scenario, the reactor exhaust would first pass over the permeation membranes to selectively remove the hydrogen isotopes and subsequently over the getter beds to remove the chemically bound tritium.

A second getter study will center on the ability of getters to remove trace quantities of tritium from noble gas streams. To date, zirconium-iron has been studied for this application. The performance of other materials will be compared against this alloy.
(CFFTP; Nuclear Generation; W.T. Shmayda/N.P. Kherani)

6.3 Power Plant Materials Corrosion Unit

6.3.1 Steam Generator Corrosion Programs

Stress Corrosion Cracking of Tubing Alloys

Substantial work is to be performed in this area in 1987. Testing will proceed on two test loop facilities utilizing both rod and tube samples, and in autoclaves utilizing C-ring and U-bend samples.

Testing will first concentrate on exposure of N06600 with a susceptible microstructure to conditions that cause cracking; acceleration will be through the use of heat treatment of test specimens, high temperatures, high levels of dissolved gases, and high pH. When cracking has been established successfully, the severity of test conditions will be reduced to determine limits of susceptibility.

Most testing will be carried out with material in a susceptible condition to maximize the amount of cracking data obtained. Additionally, some material will be heat treated to minimize the cracking susceptibility; tests that produce cracking for all material conditions will then be used to rank the degree of susceptibility of actual tubing for correlation with results from the bulk of the test program and data from external sources. (TTSD; COG; Nuclear Generation; P.J. King)

Pitting and Crevice Corrosion of Tubing Alloys

Pit initiation and propagation behaviour will be examined in aggressive solutions (oxidizing, high chloride), but with no crevices or heat flux, to obtain initial estimates of pit growth rates and growth limits. Subsequent testing will include first a thermal gradient, and then a crevice. The concentration of aggressive components will be reduced to determine the limits of susceptibility to localized attack.

The test program will involve exposure testing of tube samples that may be internally or externally heated. (TTSD; Nuclear Generation; P.J. King)

Evaluations of Tubes Removed from Service

Corrosion assessments will be provided as required. The coordinating role is to be developed further to provide more effective service for client groups. An overall assessment of tube condition in Ontario Hydro Steam Generators will be formulated based on the results of past tube examinations and failure analyses, and additional tube examinations.
(TTSD; Nuclear Generation; P.J. King)

6.3.2 Heat Exchanger Corrosion Programs

Laboratory Electrochemical Testing

These will continue in 1987 to study localized corrosion and to obtain corrosion rates of alloys N08800, N08825 and N08028. In addition, alloy N06625 will be tested. The projects include:

- Completion of potentiostatic polarization tests started in 1986 to study pit initiation and to obtain pit propagation rates.

- Performance tests to study crevice corrosion by using artificial crevice cell and by depositing calcium carbonate onto the test alloy. It is expected that crevice corrosion rates will be obtained from these tests.

(TTSD; Nuclear Generation; K.W. Lam)

Laboratory Immersion Testing

Will continue from 1986 to study temperature effects on the initiation of pitting and crevice corrosion of heat exchanger materials in the absence of electrochemical acceleration. One year exposures will be completed and additional tests will be initiated.
(TTSD; Nuclear Generation; K.W. Lam)

Test Rig I

The Pickering test rig will continue to be used to test the effectiveness of biocide and dispersant in minimizing deposit formation and subsequent localized corrosion. It will also be used to study flow effects and environmental changes on heat exchanger deposits.
(TTSD; Nuclear Generation; P.J. King)

Test Rig II

The Darlington test rig will be used to assess the corrosion performance of potential replacement heat exchanger materials. Long term test exposures of from one to four years will begin.
(TTSD; Nuclear Generation; P.J. King)

Fundamental Studies

The work on experimental alloys will continue. Emphasis will be on determining propagation rates in concentrated electrolytes by employing an artificial pit technique and performing potentiostatic tests. As well as rate data, information will be obtained on the conditions (potential/current density) required to maintain active propagation of attack. This information will be useful in estimating possible limits to localized corrosion of tubing in service exposure.
(OHRD; Nuclear Generation; P.J. King)

Turbine Rotor Disc Stress Corrosion Cracking

Exposures of specimens to a 10% caustic solution in test series #3 will be completed in 1987. Fracture mechanics assessments and metallographic examinations will be performed to obtain cracking information. Results will be compared with those from test series #2 (condensing steam). (TTSD; Nuclear Generation; P.J. King)

Pitting Corrosion of Primary Heat Transport System Materials

Preliminary experiments will be performed to observe if solution flow has any effect on pit growth of carbon steel under shutdown conditions. The compact flow system developed and built in 1986 will be tested and used in the study. Artificially pitted carbon steel coupons will be potentially controlled. Observation of an increase in corrosion current under flow will signify influences of flow on pit growth. (OHRD; Nuclear Generation; K.W. Lam)

Waste Container Corrosion

It is expected that in 1987, the present experimental program in evaluating copper's performance under various parameters that could cause or enhance its corrosion will be completed. An assessment of the suitability of copper as a container material will be provided based on its corrosion performance observed from the experimental program.
(OHRD; Nuclear Generation; K.W. Lam)

7.0 OVERVIEW

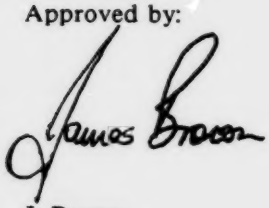
1986 continued to be characterized by major increases in the demands made upon section staff. Major short and long term programs initiated in the Zr corrosion field continued to respond to the urgent need for reliable prediction data and analysis to plan future fuel channel maintenance such as REFAB, SLAR and retubing. Zr corrosion work was related to oxide growth/morphology, the effects of water chemistry, temperature, oxide thickness, material composition and microstructure, carrier bundle coupon production, as well as corrosion/deuteriding modelling. These continued to require a very significant contribution by staff to construct testing facilities, to carry out accelerated and scoping tests and to provide expert consultation. These activities consequently reduced proportionately the effort planned on longer term work. Work in the Heat Exchanger area continued at a high level in 1986, in support of programs to assist with replacement material decisions at Pickering and Darlington. Extensive work in building two HX rigs reduced our efforts in HX materials, electrochemical testing and again resulted in our inability to undertake a full program of steam generator tube testing. For the second year in a row, the largest increase in our activities resulted from the combined large scope and fixed schedule for TIS work sustaining a quadrupling of staff requirements for part of the year - a need met by employing temporary contract staff and renting of staff from other divisions. This design/fabrication work is now essentially complete. Tritium technology programs related to fusion engineering also increased in response to added CFFTP emphasis on building lateral business opportunities. Construction of the major components of the New Tritium Laboratory were completed and commissioning was begun. Research in the thermal generation area was maintained at a minimum level to ensure current and future unit reliability and efficiency. Effort was further reduced in corrosion studies of irradiated fuel waste container materials - a result of staff resources depleted of capacity to maintain this work.

The 1987 work program will again be dominated by a continuation of key work on Zr corrosion, Heat Exchangers/Steam Generators, and assistance with TIS commissioning during the first half of the year. Research is underway with updated review status reports in Zr corrosion modelling, Heat Exchanger corrosion studies and planned Steam Generator studies expected in the first quarter of the year. Additional laboratory space finally being completed this year should help increase the capacity for continuation and further development of required Zr corrosion and Tritium Technology research programs. With the Heat Exchanger rig testing programs having been well established during 1986, and now running, electrochemical testing will receive the highest priority and as well, more effort will be devoted to defining and initiating required Steam Generator research in 1987. TIS site commissioning assistance work will be completed by year end and the new tritium lab is expected to be in full operation by the second half of 1987. Asymmetric permeation work, and getter work supported and promoted by CFFTP has established a broad base of knowledge/expertise and experimental facilities that will during 1987 generate outputs for evaluation of significant commercial potential as well as direct application to Darlington TRF operation. The scope of work planned for the Thermal Generation field, and corrosion studies of nuclear fuel waste containers will remain at a minimum effective level.

Limitations associated with bringing on new staff will continue to result in the need to consolidate program activities to meet the required corporate objectives in the highest priority areas. Concentration on key programs in Zr corrosion, Heat Exchanger/Steam Generator and Tritium technology will dominate section activities in the short term. Medium to longer term plans at this time call for building of even greater depth in each of these concentrated program

areas with planned funding from CANDEV, CEA and possibly EPRI, and by initiating increased co-operative research with Universities as well as AECL. Planned new staff additions in 1987 are expected to be implemented to maintain and build more effect programs in S/G corrosion, corrosion engineering, and Zr corrosion.

Approved by:



J. Brown
Manager
Metallurgical Research Department

Prepared by:

P.C. Lichtenberger
Supervising Scientist
Corrosion & Tritium Technology Section

PCL:md

8.0 PUBLICATIONS AND PRESENTATIONS - 1986

P. Mayer and A.V. Manolescu, "Measurement of Dissolved Hydrogen to Monitor Corrosion in High Pressure Boilers". Published in Materials Performance, February 1986.

A.C. Headon and H.T. Chan, "Corrosion of Metals in Coal Ash: A Field Study", 7th International Ash Utilization Symposium and Exposition, Orlando, Florida, March 4-7, 1986.

W.T. Shmayda, N.P. Kherani, F. Waelbroeck, J. Winter and P. Weinhold, "Tritium Pumping Based on Asymmetric Permeation", 2nd National Topical Meeting on Tritium Technology in Fission, Fusion and Isotopic Applications, Dayton, Ohio, April 29-May 2, 1986.

W.T. Shmayda, J. Winter, F. Waelbroeck and P. Weinhold, "Radial Atomic Hydrogen Flux Measurements to the TEXTOR Liner", Plasma Surface Interaction Conference, Princeton, New Jersey, May 5, 1986.

W.T. Shmayda and N.P. Kherani, "Gas Handling Systems Using Titanium Sponge and Uranium Bulk Getters", 2nd National Topical Meeting on Tritium Technology in Fission, Fusion and Isotopic Applications, Dayton, Ohio, April 29-May 2, 1986.

W.T. Shmayda, "Ontario Hydro Research Division Tritium Handling System", CNA Conference, Toronto, June 10, 1986.

N.P. Kherani and W.T. Shmayda, "Bulk Getters for Tritium Storage", Canadian Nuclear Association Conference, Toronto, June 10, 1986.

R. Reesor, M.K. Murthy and P. Mayer, "Assessment of the Energy Use in the Traditional Ceramic Industry in Canada", CEA No 515 U 528, October, 1986.

A.V. Manolescu, P. Mayer and F. Chiarotto, "Failure of Low Pressure Feedwater Heater Tubing. A Case History". Paper presented at NACE Corrosion /86 Conference, Houston, Texas, March 1986.

F. Chiarotto, A.V. Manolescu, D. Sidey and P. Mayer, "An Investigation of Low Pressure Feedwater Heater Tube Failure. Paper presented at the ASME/IEEE Power Generation Conference, Portland, Oregon, October, 1986.

V.R.D. Miller and A.V. Manolescu, "Maintenance Strategy and Specific Design Changes to Ontario Hydro's Lambton TGS Coal-Fired Generating Units to Mitigate the Effects of Solid Particle Erosion", Paper presented at NACE Eastern Canadian Regional Conference, Halifax, November, 1986.

W.T. Shmayda, N.P. Kherani and J. Winter, "Permeation Probes: A New Atomic Hydrogen Diagnostic for Fusion Devices", Journal of Nuclear Materials, November, 1986.

DISTRIBUTION

Dr. D. Mills	Director of Research
Mr. B.R. Collingwood	Dsgn & Dev - Gen, H15D02
Mr. Z.J. Janik	Dsgn & Dev - Gen, H15A15
Mr. I.J. Stuart-Sheppard	Dsgn & Dev - Gen, H13A01
Mr. H.N. Isaac	Dsgn & Dev - Gen, H11G27
Mr. T.J. Carter	Dsgn & Dev - Gen, H11A27
Mr. J.S. Li	Dsgn & Dev - Gen, H11F27
Mr. R.E. Pauls	Dsgn & Dev - Gen, H11A16
Mr. J.P. Oreskovich	Dsgn & Dev - Gen, H15G01
Mr. D.W. Souther	Dsgn & Dev - Gen, H10A01
Dr. G.J. Field	Dsgn & Dev - Gen, H10A16
Mr. P.D. Stevens-Guille	Dsgn & Dev - Gen, H10A14
Mr. J.T. Martin	Dsgn & Dev - Gen, H14A21
Mr. P.R. Burroughs	Dsgn & Dev - Gen, H15B01
Dr. R.A. Brown	Dsgn & Dev - G, H11A01
Mr. N. Hanssman	Dsgn & Dev - Gen, H14A27
Mr. J.R. Webb	Dsgn & Dev - Gen, H15B02
Mr. G.E. Fraser	Dist Systems, U06A06
Mr. O.K. Kveton	Fusion Centre
Dr. D.P. Dautovich	Fusion Centre
Dr. K.Y. Wong	Fusion Centre
Dr. C.D. Burnham	Fusion Centre
Mr. A.B. Meikle	Fusion Centre
Mr. J.R. Freeman	Market Devlp, C25A03
Dr. T.S. Drolet	New Bus Vent, C27F1
Dr. R.C. Oberth	New Bus Vent, C27F2
Mr. B.R. Churchill	BNPD Proj, H18A01
Mr. J. McCredie	Darl Proj, H16A27
Mr. M.A. Machacek	Darl Proj, H16G01
Dr. W.B. Stewart	Darl Proj, H16G05
Mr. R.J. Strickert	Tech & Trg Ser, A07H02
Mr. B. Montford	Tech & Trg Ser, A07H09
Dr. M.W. Shanahan	Tech & Trg Ser, A07H08
Mr. R.W. Dyck	Tech & Trg Ser, A07F08
Mr. C.S. Lacy	Tech & Trg Ser, A07F10
Dr. G. Brenciaglia	Tech & Trg Ser, A07A13
Mr. R.W. Patterson	Tech & Trg Ser, A08H06
Mr. P.R. Stratton	Supply, H06A27
Mr. A.B. Cook	Bruce NGS 'A'
Mr. J.L. Bagshaw	Bruce GS 'B'
Mr. G.D. Davidson	Bruce Heavy Water Plant
Mr. T.W.B. MacFarlane	Lakeview GS
Mr. D.G. Shelton	Lambton GS
Mr. R.E. Lewis	NPD GS
Mr. H.J. Kirwin	Nanticoke GS
Mr. J.W. Free	Pickering NGS 'A'

DISTRIBUTION (Cont'd)

Mr. D.R. McQuade	Darlington NGS
Mr. R.B. Davidson	Darlington NGS
Dr. J. Brown	Metallurgical Research
Mr. G.J. Clarke	Mechanical Research
Mr. A.F. Baljet	Electrical Research
Dr. M. Booth	Chemical Research
Dr. T.W. Klym	Civil Research
Mr. J.G. Cassan	Operations Research/Divisional Projects
Mr. J.B. Brown	Divisional Services
Dr. P.C. Lichtenberger (3)	Metallurgical Research

Public Reference Centre
Editorial Section (2)
Office Copies (3)
Extra Copies (3)